554

Spatial characteristics of mixed-use typologies in a tropical metropolis

Understanding how retail podia relate with the urban realm

PANAGIOTIS MAVROS 1, YUQIN ZHONG 2, CHRISTOPH HÖLSCHER 3

1 SINGAPORE ETH CENTRE, SINGAPORE, 2 SINGAPORE UNIVERSITY OF TECHNOLOGY AND DESIGN, SINGAPORE, 3 ETH ZÜRICH, SWITZERLAND

ABSTRACT

In this paper we examine the spatial characteristics and evolution of the high-density mixed-use buildings, specifically the podium-and-tower typology where several retail floors are topped with a residential or office high-rise. We focus in particular on the popular shopping-mall-in-podium cases, a typology that is increasingly popular in SE Asia as part of transit-oriented developments, but with divergent approaches on spatial configuration. Because of their prevalence, there is a need to understand how the typology evolved during the past decades, the major trends in its configuration and their spatial implications from their indoor complexity to how they relate to the surrounding urban fabric. To explore this, we digitised floor plans from more than 30 podium-and-tower shopping malls across Singapore, incorporating exemplary buildings from the last 50 years. We analysed their main floorplate (typically the retail ground floor) using an isovist-based measure of outdoor visual access. An urban design audit captured the properties of the building perimeter using walkability indicators. Together, these metrics provide formal descriptions of the indoor spatial configuration of such mixed-use/retail environments, but also formally assess how they 'relate' with their surroundings – what kind of urban space is generated by the building itself. We describe the evolution of this typology, different ways of relating and activating the city, connecting the interior and exterior spaces. In conclusion, we argue for more typology studies and a close look on how the podium-mall shapes its urban environment, especially due to their strategic importance and implications in the design of future mixed-use urban developments.

KEYWORDS

Mixed-use buildings, podium, space syntax, urban design, urban design guidelines

1 INTRODUCTION

High-density mixed-use developments are proliferating in many rapidly evolving cities and metropolises in monsoon Asia, often taking the shape of the podium-and-tower typology, where a multistorey, retail base (the podium) is topped by a high-rise tower that contains office, residential and other uses (Lau & Zhang, 2015). Because of their widespread adoption, in central and regional areas, as part of individual developments or transit-oriented precincts, the spatial configuration and overall design of the podium-and-tower (especially at the ground-level retail), play a major role on the appearance and functioning of the surrounding urban realm.

More specifically, the design and configuration of activities along the façade influences pedestrian perception and overall street-level activity (cf Gehl et al 2006). In addition, the spatial configuration of the interior layout influences the overall intelligibility but also how the interior connects with the exterior urban space to create a visuospatial coherence. Although both these components (indoor layout and façade) are important for the kind of urban space generated, there is a wide diversity of how these are designed. Despite their importance for the urban realm of many cities, and ample scholarship coming from retail studies, podium-and-tower and shopping mall typologies there is not a standardised approach to assess who they relate with their surroundings. Here we adopt a joint urban-design and syntactical approach to understand how this common typology is designed over the decades, and across different modes of development and ownership.

In most cases, the design of such developments is shaped by two design paradigms: the shopping mall, as it has developed over the years in various countries (Wee and Tong, 2005). The shopping mall has evolved from the monofunctional urban department store (Steadman, 2014) and later the suburban sprawl retail centre (Harwdick, 2010). In land-scarce, high-density metropolises like Hong Kong and Singapore, this typology was moulded to the local urban fabric and land-use patterns, diversifying land-use by stacking additional building programmes focused on office, residential activity. Progressively, this evolved into the current podium and tower mixed-use building that is proliferating today (e.g. Lau & Zhang, 2015; Seng, 2013). Multiple factors played a role in this. Beyond real-estate pressures, the tropical climate of these cities (or the cold climate of other cities such as Montreal)[1], made covered and air-conditioned public, but privately owned, spaces an appealing alternative to typical street-based retail centres. Public housing developments built in the late 1970s - 1980s initiated the combination of a commercial podium characterised by small shop units and design features adapted to the tropical climate, such as multiple open-air atria, and evolving today to private developments that vertically integrated multiple land-uses.

[1] Characterised by high-levels of sunshine and humidity throughout the year and especially during the monsoon by sudden and intense rainfalls. The timing of the rain season, or monsoons, differs between geographic regions in SE Asia.

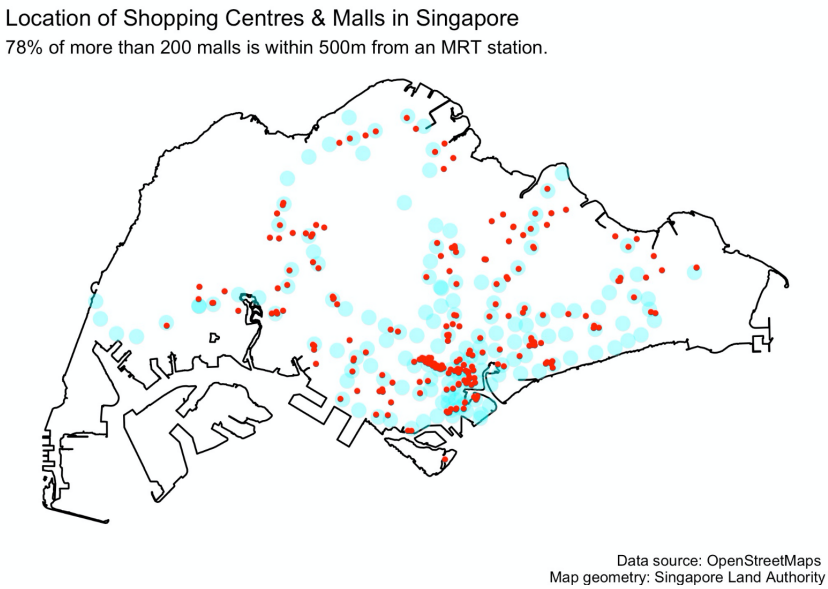

Figure 1: Map of Singapore indicating the locations of shopping malls and shopping centres (red dots). Blue circles indicate a 500m radius from a Mass Rapid Transit (i.e. metro) station. Approximately 78% of the shopping malls are within this radius, suggesting a strong trend towards transit-oriented developments.

Due to their strategic placement in the urban landscape (Figure 1), at the centre of urban redevelopments, new towns and transit-oriented developments, many of these buildings – and the entire typology as a whole – rather than merely serving a retail function, they also have an important status in the urban imaginary. In their review of public space typologies of Singapore (Kiang, 2009) notes that in the history of urban development of Singapore, commercially driven public spaces have become an integral part of the "urban life and consciousness […] beyond the physical confines of their buildings as acts of civic responsibility and/or marketing tools" (Kiang 2009, 235). In this context, it is important to describe the spatial evolution of this typology and understand the implication of different design patterns on the individual user as well as the urban realm – in other words, the community.

The present work

In this context, the aim of this paper is to investigate the spatial configuration of high-density mixed-use buildings, focusing on the urban shopping centre (mall). Our objective is to assess how architectural decisions influence the indoor layout and the interface between the building and the urban realm (i.e. the façade), and observe how these parameters have evolved over time. Specifically, this study addresses the following questions:

- What are the spatial characteristics of this building type?
- What are the properties of the building type in terms of factors that influence the urban realm and neighbourhood vitality and walkability?
- What are the properties of the building type in terms of factors that are critical for wayfinding behaviour?

2 THEORETICAL FRAMEWORK

In the present section we discuss the background and theoretical consideration of the present research.

The podium-and tower typology

The podium and tower building typology can be defined as a mixed function base of 4-5 floors (~50-foot- / 15-metres), which typically extends to cover the entire plot, and is topped by a residential high-rise tower (Lau & Zhang, 2015). The typology emerged as a progression from the modernist free-standing tower block, where the base incorporated mixed functions and extended until the plot-line, thus re-establishing the street boundary façade. Progressively, the plot and associated podium grew larger, and the towers increased in number and height, leading to what Lau and Zhang (2015) call 'hyper podium+tower' and 'super high-rise podium+tower', that have become typical of many cities especially in East Asia, e.g. Hong Kong, Singapore and others.

From its onset, the podium and tower typology had the objective to accommodate diverse types of uses, including retail, office and other. In Hong Kong, the podium-and-tower type was fused with the earlier paradigms of the department store, shopping centre and shopping mall types (Shelton, 2020). Singapore also adopted this model, to compensate for land scarcity – similar to HK – early examples of the typology, such as Tanjong Pagar Plaza (completed in 1977) or Bras Basah Complex (completed in 1980), combined a shopping centre podium with a multi storey residential tower (these are described in the Analysis section).

In practice, the podium and tower typology has become a canonical solution for urban development, being designed for both developments in the central, regional and peripheral urban areas. In Singapore, the great majority of new retail developments adopt the podium-and-tower typology. This is particularly the case for transit-oriented developments (TODs). The podium-and-tower typology provides an effective combination of high-density in terms of both population and land-use in a given plot or city block, and thus it is advantageous for densification and intensification of the urban fabric in areas surrounding TOD.

Transit-oriented developments & Mixed-use

The term 'transit-oriented development' was proposed by Peter Calthorpe in 1993 to describe a planning concept advocating for the intensification of land-use (residential, employment, commercial, recreational and other activities) in a walking distance around public transit stations (for recent reviews see Knowles et 2020; Ibraeva et al 2020). Of course, as Knowles et al argue, urban development historically goes hand in hand with transit modes, starting with the "development of suburban housing along new rail and streetcar (tram) lines" in late 19th century, and similarly the automobile-based suburbanisation of the second half of 20th century (Knowles et al., 2020). Cities like Copenhagen, Hong Kong, Singapore and Seoul, increasingly invested in public transit and TOD since the 1970s, and more cities followed-up in recent years (Knowles et al., 2020).

There are multiple benefits associated with TODs both at the city and the individual level. These include reduced reliance on car-ownership and use, increased walking and cycling for transport. more efficient land-use and more. A concentration of mixed land uses generates bi-directional travel demand throughout the day (e.g. Loo, Chen and Chan, 2010). Reduced use of private transport and more efficient use of infrastructure, also make TODs an important component of sustainable urban developments, especially in the light of climate change and the need to reduce carbon emissions.

However, the success of new TODs varies depending on the spatial characteristics of the infrastructure, the overall masterplan and individual developments. Calthorpe and others identified seven key characteristics for successful TODs: Density, Diversity, Design (of the urban fabric), Distance-to-transit, Destination accessibility, Demand management, High Frequency (Cervero and Kockelman 1997; Knowles et al 2020). Supporting active transport (walking and cycling) is especially important, but greatly depends on the urban form. For example, Lu et al (2018) found that TOD in Hong Kong's new towns that have fewer pedestrian destinations, and a more complex urban layout were associated with lower rates of walking for transport or leisure compared to typical HK urban areas. "The street network design and land-use mix are most strongly associated with walking shares, when controlling for population density, transit service characteristics, and personal attributes" (Ozbil and Peponis, 2012). TOD areas in traditional neighbourhoods (on average and overall) outperform integrated development neighbourhoods (Lang et al 2020). Therefore, it is important to not only study where TODs are located, and their overall characteristics (FAR, area, etc) but also how they are implemented spatially both at the urban *and* at the architectural levels.

Singapore and TOD

There are multiple reasons to study high-density mixed-use typologies in Singapore. Singapore is a country of 5.45 million people, a total size of 728.3 square kilometres, and high-population density 7,485 persons per sq.km. At approximately 1 degree north of the equator, Singapore has a tropical climate, characterised by relatively high temperature (approximately 30º Celsius) and high humidity throughout the year (mean annual relative humidity is 83.9%). The combination of large population, land-scarcity, climate, and urban planning policies during the past 50 years, as well as other factors, have led to the proliferation of high-rise buildings.

Moreover, Singapore's urban form has been shaped following a transit-oriented development framework. Yang and Lew (2009) discuss the planning history of Singapore and the progressive shift towards transit-oriented developments at a national scale since the 1970s. As they account, in Singapore, early public housing estates were situated in vicinity (within 6km) from the city centre, with a 30% provision for parking. However, starting with the 1970 'concept plan' a decentralisation strategy of urban growth along transit corridors was articulated. Following this plan and the development of new mass-rapid transit (MRT) lines, new towns were distributed along transit corridors extending from the centre towards an east-west and a north-south axis. In both central areas and new towns, increased density and land-use intensification can be observed in (walkable)

proximity to public transit. Today, Singapore has 6 MRT lines with more than 120 Stations, and more in development.

The focus on transit-oriented urban development influenced the type of urban developments built by public organisations. The Housing & Development Board (HDB) built during the late 1970s - 1980s combines a commercial podium characterised by small shop units and design features adapted to the tropical climate, such as multiple open-air atria (Chang, 2000). Effectively the podium functions as the courtyard and public space outlet for the residential tower that extends above it. A notable difference, Kiang & Liang (2009) note, is that the commercial nature and permeability of these public spaces attracts non-residents creating a mix of functions, activities and populations. In line with this observation, Niu et al (2019) measured a higher mixed-use entropy in TOD than non-TOD estates.

In this context, Singapore's urban development provides both a motivation as well as a large number of potential case-studies to examine the evolution of the typology of the tropical mixed-use high-rise buildings, transit-oriented developments and neighbourhoods, and their impact on the urban realm.

Analysis of built form

There is a long history of analysing built forms to understand the properties of the spatial configuration (Hillier and Hanson, 1984) or the properties of architectural and urban design (Gehl et al., 2006; Ewing and Handy, 2009). These analyses can vary in scale, from individual buildings to entire neighbourhoods, and studying various outcomes such as pedestrian flow, walkability, health and other aspects. Several studies have analysed the urban form of TODs to better understand the relationship between their spatial characteristics and their performance in terms of mode share, walkability, social and economic performance. Many studies focus on spatial measures, such as FAR, intersection density, integration and segregation and other composite metrics (e.g. Berghauser Pont 2014).

One specific aspect that influences the subjective experience of places, but also relates with urban vitality is the *interface* between the exterior and interior spaces – typically how building façades enable or hinder physical or visual access to the ground level spaces (van Nes, A., & Yamu, 2021). These interfaces can provide interaction, activity, interest, or distraction (Gehl et al., 2006). Dovey and Symons (2014) developed a system to map the "morphology of the public/private interface" and how it supports street life and urban vitality. They defined 5 categories of interfacing between the building and street, depending on the directness of either physical or visual access, as well as the setback.

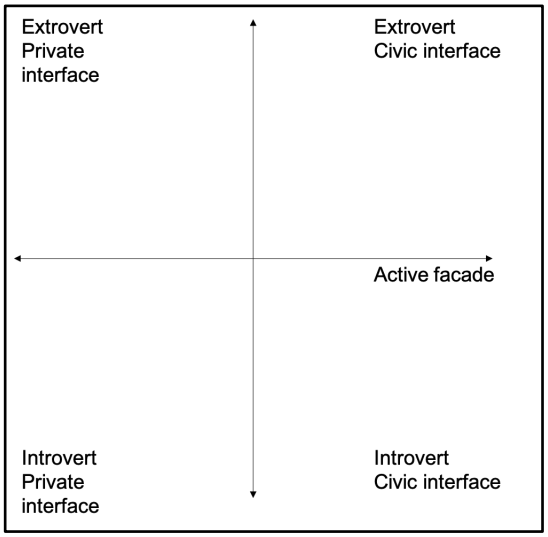

Figure 2: Proposed conceptual model of how active façade and outdoor visual access, generate different types of interface between individual buildings and the urban realm.

Stojanovski (2020) analysed commercial areas in various Swedish cities, analysing viewsheds. Mcallister and colleagues (2019) mapped this interface, in terms of active façades, and their design qualities. As Pafka and Dovey (2017) note, it is essential to study both the extent of spaces accessible to pedestrians but also what is indeed accessible: "what is at stake is not only correlations with health and transport, but also measures of walkable access that are geared to the social and economic productivity of the city" (ibid, p. 156).

In this line of research, the spatial configuration of the interior and how it impacts its relationships with the exterior urban realm has not been sufficiently linked. Clearly an active façade enables access to the street and vice-versa, but how about other inner spaces?

Interior spaces have also received extensive attention especially in the space syntax tradition, quantifying their spatial configuration, affordances for movement, complexity, intelligibility etc. The spatial configuration of interior (architectural) space has implications for the occupancy and movement patterns, and the overall building usability (e.g. Weisman, 1981; Natapov et al 2015; Krukar et al 2014).

Turning to mixed-use buildings and/in transit-oriented developments, as discussed earlier, there is a need to better described and understand their design, and how they support urban life – walkable and vibrant urban environments. While there are multiple frameworks to analyse urban or building form, either from the exterior or from the interior, here we proposed to merge both approaches. Figure 2 illustrates a conceptual model that consists of both elements. On the x-axis, the degree to which a building interfaces with the street with an active-façade influences what activities are possible at the street level, how the building is perceived and the overall experience in the urban realm of that building. On the y-axis, the degree to which the interior space visually accesses the outdoor space

influences how embedded, or isolated, the building is in its surroundings. Typically, in small developments, most spaces / rooms behind the façade have windows; in residential or workplace environments these spaces are where most activities take place. However, in large scale buildings, from hospitals to shopping malls, there is an important component of circulation spaces that is visually segregated from the exterior space. This can contribute to wayfinding difficulties and the experience of space.

2.1 The present work

In this paper, we trace the evolution of the mixed-use typology in Singapore, focusing on shopping mall buildings. Singapore has 231 shopping malls out of which 166 (72%) are within 400m, and 113 (48%) are within 200 metres from an MRT station (authors' analysis of OpenStreetMap data). As such, not only is it important to understand how these buildings generate and influence the urban realm around them, but equally, there is a sufficient variety of case-studies to examine the different incarnations of the typology.

In the following sections, we select a subset of 34 shopping malls, located in mixed-use building within transit-oriented developments and urban districts, and perform the two types of indoor and outdoor spatial analysis outlined above (see below for details) in order to understand how these buildings produce urban space, and how they 'engage' with it.

3 DATASETS AND METHODS

In this section we first describe the rationale and method for establishing a database of mixed-use building floorplans, and then the development of our analysis framework.

3.1 Building floorplans

Thirty- four (34) mixed-use buildings from Singapore were selected for analysis. The selected buildings were primarily shopping centres and malls, the majority belonging to the podium-and-tower typology. The case-study buildings were selected to have a wider geographic distribution of Singapore, covering both central and peripheral areas of Singapore, built across different decades and of different size (Figure 1). They also include various types of development and ownership structures: publicly and privately built, build-to-sale and build-to-rent.

For the purpose of the present paper, we analysed only one of the floors for each building. Building floor plans were obtained from publicly available sources (such as public maps and evacuation diagrams). One floor level was chosen for each building according to its importance for the functionality of the building as well as for its connectivity with its surroundings. In the majority of cases this was the level of the main entrance at the street-level. The plot layout for each building was obtained from Singapore's masterplan.

3.2 Analysis framework

The floor plans were digitised using the software Rhinoceros (version 6; McNeel and Associates, 2020). The floorplans were imported in Rhinoceros, brought to scale when necessary, and all boundaries (e.g. walls, glass façades, entrances) were traced as polylines and then submitted to an urban design audit and to isovist-based spatial analysis. The floorplans and their axial representations were analysed in the following steps, in the Rhinoceros 6 CAD software (McNeel, 2020) and the built-in scripting environment Grasshopper (GH), using the plugins: DeCodingSpaces, Beghest, and Elephront. The site boundaries of each building plot were obtained from Singapore's 2019 masterplan (building layer) and was manually superimposed on the building floor plan. After establishing a digitised drawing of the interior and exterior (urban) space for each building, we computed several analytical and syntactical measures to describe the interior space and how it relates with the surrounding urban realm. We discuss these in turn.

Analysis of interior spaces

Each floor plan was submitted to isovist analysis. First, a measure of outdoor visual access was established by computing the cumulative visibility to the exterior (Figure 3). A circle with a radius of 500 metres was created from the centroid of each plan. For each vantage point, we computed the intersection between the circle and the isovist and computed the angle of visible arcs in degrees (similar to the measure of exterior view length by Schneider et al., 2014). This measure was devised to gauge the proportion of the external environment (i.e. not the building itself) that is visible from any given vantage point. In some cases, the isovist consisted of multiple outside views, thus the minimum, maximum and average angle was computed for each vantage point.

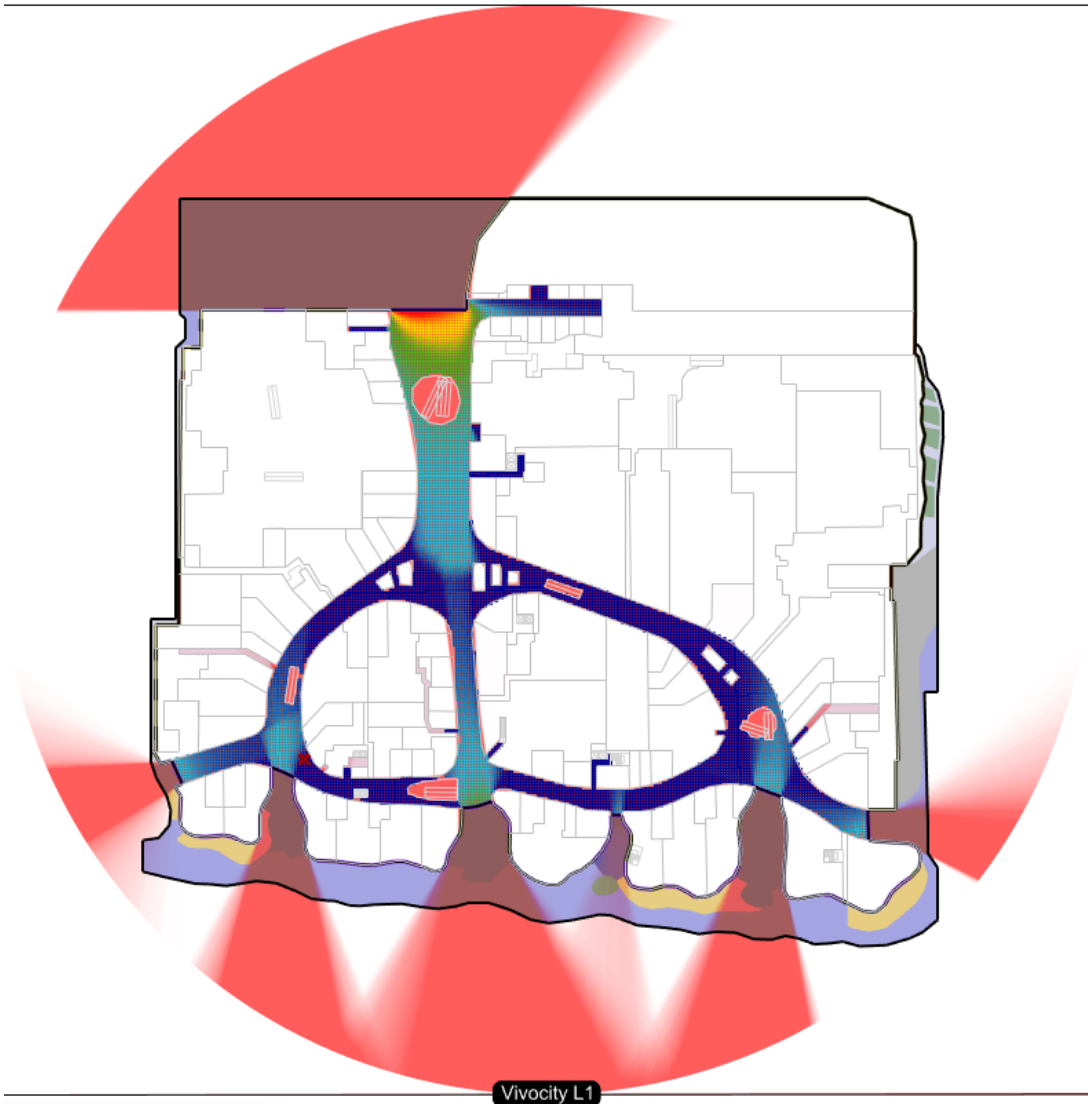

Figure 3: Example of the metric of outdoor visual access from one of the case-studies. A 1-m grid is used to compute the intersection between an isovist and a circle surrounding the building. This allows the calculation of none, one or more visible arc (s) from each point. The isovist field presents the sum of visible arcs (in degrees) for each point, while the measure of average outdoor visual access corresponds to the average of all points of the isovist grid.

Analysis of exterior spaces

The following two types of exterior spaces analysis are then carried out: 1) ground floor building façade; 2) building boundary space. Both represent the linkage between the interior spaces of a building and the urban public spaces, which have the ability of attracting pedestrians.

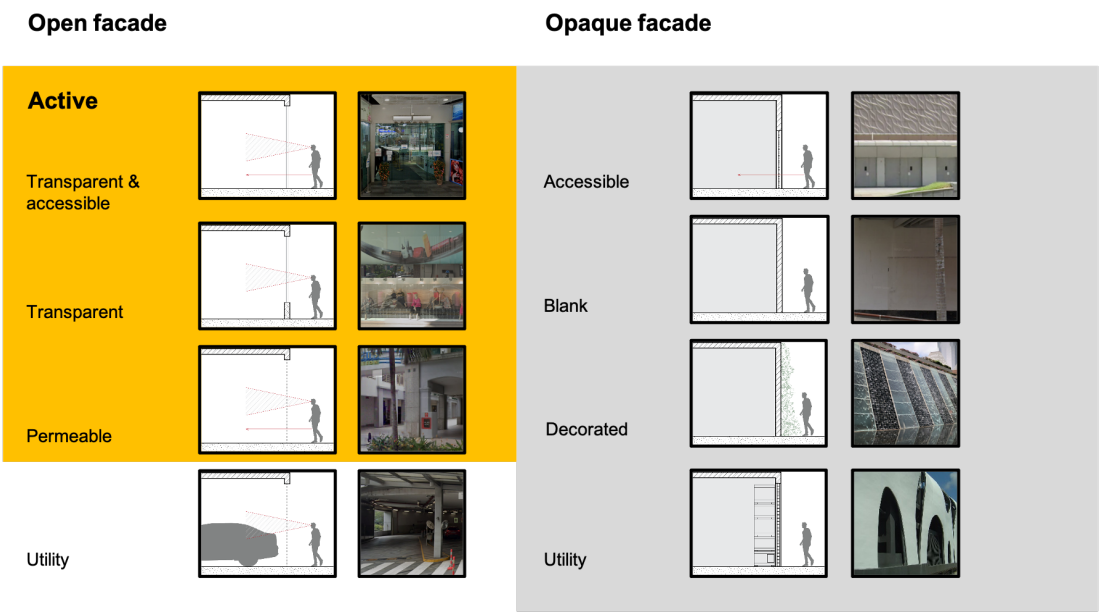

Figure 4: Diagram of analysis of exterior spaces. (A) building façade types shown in plan and section. (B) Building boundary space analysis.

Building façade analysis

The building façade is defined as the external face of a building, which is the interface between the exterior and interior spaces. In our analysis, we have categorised the façades into 2 major categories and 8 subcategories, according to their level of openness and pedestrian interaction. The categories are defined as below (Figure 4):

The major categories are **Open façade** and **Opaque façade**. An **Open façade** segment contains no opaque vertical partitions separating the interior and exterior spaces. Therefore, it allows either physical or visual access by pedestrians or vehicles. Within this category, the **Permeable Public façade** allows pedestrian entrance into the internal space and the **Permeable Utility** façade targets vehicular or utility access instead. A **Transparent & Accessible façade** segment contains a vertical partition that separates the interior and exterior spaces. However, this partition is always transparent, allowing both physical and visual access into the interior space. In contrast, a **Transparent façade** segment such as display window allows only visual access.

The second major category is the **Opaque façade** which contains a partition wall that obstructs the view completely and hinders pedestrian interaction. The four sub-categories are: **Accessible Opaque** segments which allows only physical access into the building through opaque doors; **Blank Wall** segments that comprises zero catered decoration; **Decorated Wall** segments with certain design interventions and **Utility** segments which partition unintended views to the utility areas from normal pedestrians.

Among the 8 sub-categories as explained above, the **Transparent & Accessible**, **Transparent** and **Permeable Public** façade categories are regarded as active ones. They allow either physical or visual access by pedestrians outside into the interior space of the mall, thus creating interaction in between.

For each mall in our analysis, its façade was traced into a closed-loop polygon in Rhinoceros, based on the ground floor plan obtained. It was then divided into façade segments that belong to one of the above-mentioned 8 sub-categories, according to both the given plan information, Google Street View verification and on-site observation. The total length of façade segments in each category, and their percentage length were computed and compared across the range of all selected buildings.

Other than the cross-comparison through parallel coordinates and stacked plots, the façade segments in every building were then each projected onto an equal-radius donut diagram (Figure 8) representing their respective percentage length and arrangement. This is for a direct visual comparison of façade segment arrangement across buildings, given that the façade polygon shapes and sizes vary largely.

Building boundary space analysis:

The building boundary space is defined as the open space in between the ground level façade and the site boundary. It is either a sheltered or unsheltered exterior space outside of the shopping mall's ground floor façade. Its characteristics reflect the various intentions of a development in terms of the quality and type of pedestrian activities allowed. In our analysis, the boundary space is grouped into two major categories: Active and Inactive.

An Active boundary allows pedestrians to have sufficient active physical or visual interactions with each other or with the space. Various scales of activities can be held with little or no obstruction. There are three sub-categories: **Open Plaza** space which is usually located in front of major entrances of a shopping mall. It allows relatively large public events, installations or activities to take place. An example is the open plaza in front of the main entrance of Vivo City. **Wide Walkway** space is a relatively wide pedestrian lane that is located around the building. It allows multiple pedestrians to walk along comfortably and allows some small and continuous public activities along the route. Lastly, the **Activity** space is an inaccessible area for pedestrians where relatively private activities such as outdoor dining take place. However, it still generates plenty of interactions and activities for the area.

In contrast, an Inactive boundary space is targeted for functional usages mainly, unintended for pedestrian activities. It consists of three sub-categories: **Narrow Walkway** where only minimum width for pedestrian circulation is provided; **Decorative** space where decorative features such as greenery and water feature are placed; And **Utility** space that targets non-pedestrian activities such as vehicular circulation and utility facilities.

The analysis of the **boundary space** is carried out in a similar method as the façade analysis. We subdivided the open space between the façade and the site boundary in polygons representing different activity types as described above. However, in many cases the relative area (%) of each boundary category is skewed by the uneven distribution of the overall boundary space. This is partly due to the difference in the regulations regarding building coverage ratio, building setback and greenery, and also the available empty area. To address this, we calculated an additional index, the relative length of the building perimeter (façade) allocated to each boundary space category. Besides normalising the boundary space relative to the perimeter instead of the surface area of the open space, this approach also allowed to capture the building-pedestrian interface – where pedestrians' interactions with the building occur most often.

Similarly, to facilitate the visual comparison between different case-studies, the boundary space categories were projected from the façade perimeter onto an equal-radius donut diagram to show the variety and allocation relative to the adjacent façade. The two rings of each donut diagram correspond perfectly such that they represent their relative spatial positions. This method showing the façade segment and its adjacent boundary space can reflect the level of interaction given to the pedestrians between a mixed-use building and the urban realm.

4 RESULTS

Based on our analysis framework described above, we examine how mixed-use buildings relate to the surrounding urban realm, by analysing their internal and external layout.

While a comprehensive list of shopping malls or transit-oriented developments does not exist, we generated a catalogue of shopping malls (and their location) from the crowd-sourced OpenStreetMap database, using the 'multipolygons' layer. This allowed us to compute their location (centroid), as well as their approximate size, in terms of perimeter and surface area. Other data such as number of floors, shops, parking space, etc., were inconsistent and thus not analysed further.

Figure 1 shows a total of 230 locations that were identified as 'malls' or 'shopping centres', out of which 72% were within a 400-metre radius, corresponding approximately to a 5-minutes walk, from a nearby MRT (Mass-Rapid Transit) station.

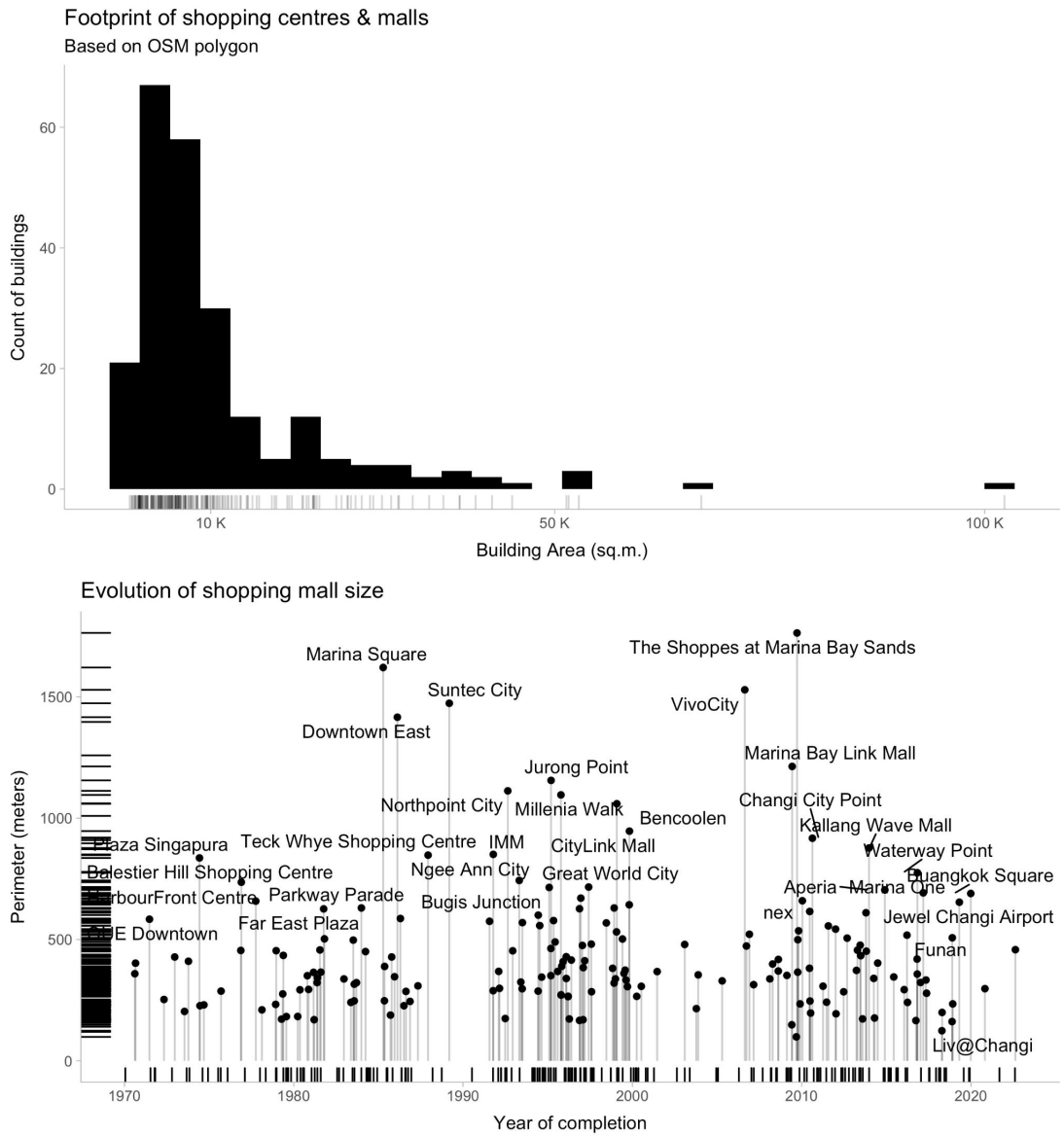

Figure 5 (A) Histogram the surface area (building footprint) of shopping malls from Singapore. (B) Timeline plot showing the perimeter of shopping malls (N = 187) according to the year of completion of each one. Overall, the average building footprint is 458 metres long, while since the mid-1980s mega-malls (more than 1km perimeter) are also being constructed at sparser intervals.

Figure 5A shows a histogram the surface area of each building (nb. the polygon of the building, not the plot), and reveals that the average shopping mall has a footprint of 10,000 square metres, ranging from 567 to 102,298 sq.m. To examine the longitudinal evolution of the typology, the construction year or date of completion was obtained for 187 out of 231 malls, while no public data were identified for the remaining buildings at present. Figure 5B shows the evolution of mall size in terms of their perimeter, revealing an average of 458 metres, with a range between 98 to 1760 metres. The timeline plot (Figure 5B) shows that in general the average size of shopping malls has remained similar, while larger malls with perimeters larger than 800 metres are built at more sparse intervals. Taken together, these suggest the typology has followed a stable profile in terms of size during the past decades, presumably reflecting real-estate and urban planning circumstances (e.g. plot sizing). Notably, even the average mall imposes a large footprint on the urban fabric (10,000 sq.meters, or 1 hectare).

To examine how this building type engages and relates with the surrounding city, we analysed how the interior circulation spaces afford visibility towards the exterior by applying the measure of *outdoor visual access,* and performed an urban design audit of the façade and surface area surrounding a building. These were applied to the 34 case-studies.

Interior spaces

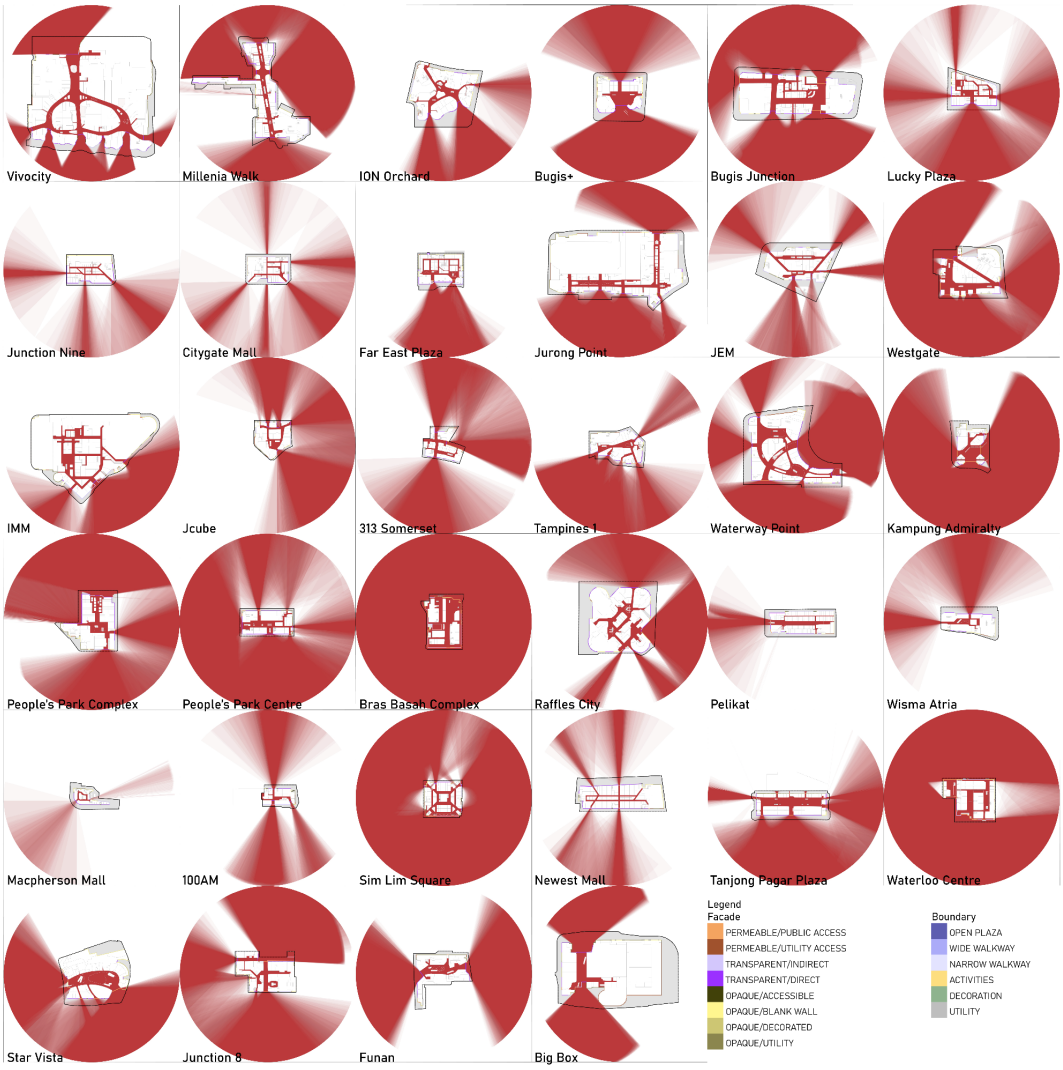

Figure 6: Diagram showing the 34 case-studies, illustrating the aggregate of isovists towards the outdoors, which serves as the base for the outdoor visual access metric. Buildings are found to vary greatly in terms of how much of their urban surroundings are visible from interior spaces.

Outdoor visual access was computed from a 1-metre grid applied to all publicly accessible circulation spaces. Figure 6 shows all 34 case-studies, illustrating the cumulative isovist to a building's surroundings. The isovists are overlaid with opacity, so that areas with high isovist coverage appear as solid, while the colour-gradient reveals less visible parts around the building. This visualisation reveals different approaches. Depending on the spatial configuration of their internal circulation, some

buildings afford views of large parts of their exterior, while others only permit views to limited directions.

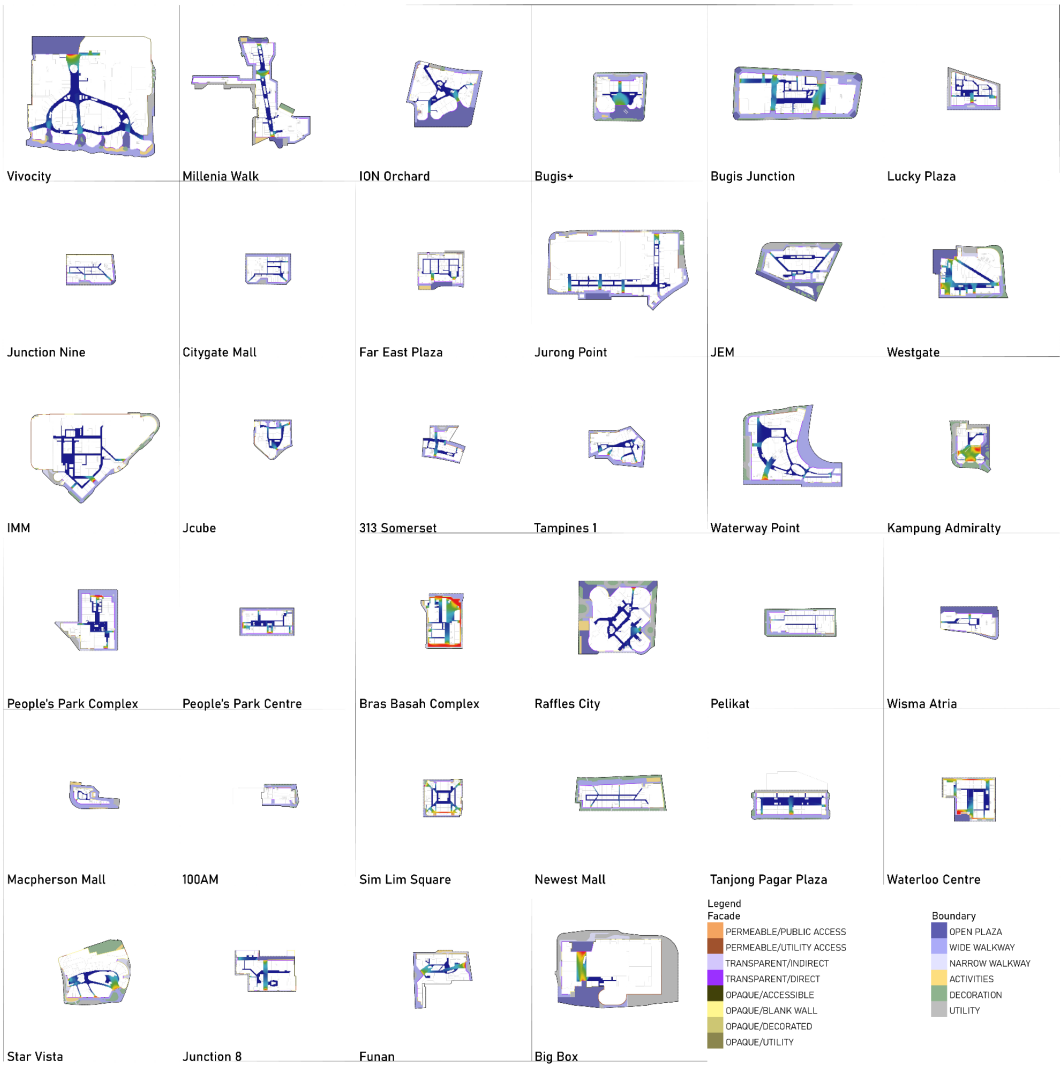

Figure 7: Diagram showing the 34 case-studies, illustrating the isovist field of outdoor visual access. It can be observed that while entrances afford good outdoor visual access, buildings vary with regards to how the interior space visually connects with the exterior. This depends on the overall depth, but also the internal layout.

Conversely, Figure 7 shows the amount of exterior space visible from each grid-point. This reveals that in most cases, while the entrances afford good outdoor visual access (at least towards one side of the building), the majority of interior circulation spaces are completely isolated from their exteriors (appearing in blue).

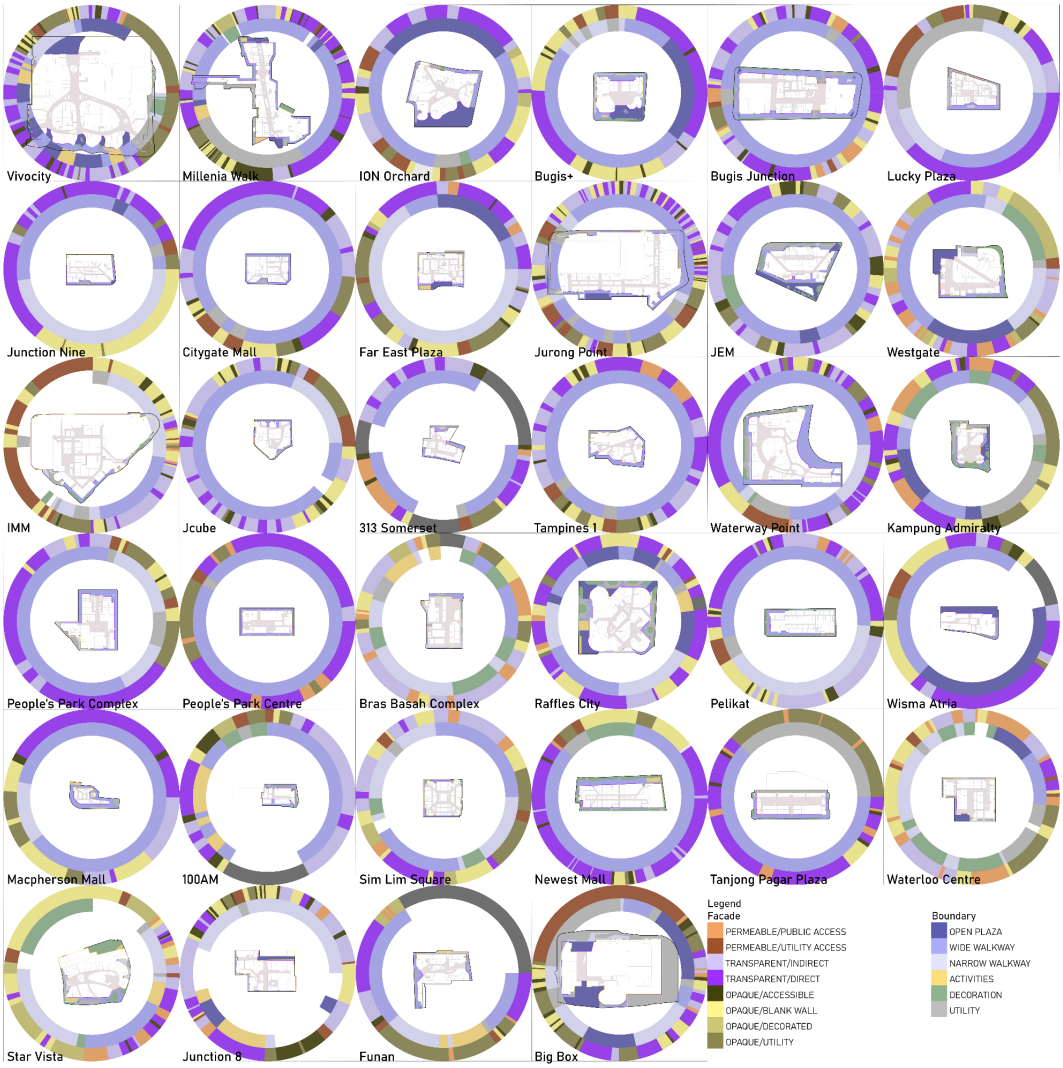

Figure 8: Diagram showing the 34 case-studies floorplans. The donut charts illustrate the allocation of the facade (outer ring) and the building boundary (inner ring; i.e. between the facade and the plot line) to different type of functions. The joint presentation of the two rings allows the comparison between the function of the facade and the public space in front.

Urban Realm

To understand how each building engages with the surrounding urban space, and the degree to which it contributes to a vibrant urban realm, we performed a visual urban design audit, classifying the pedestrian level façade and the building boundary space into different categories (see Methods for details). Figure 8 shows the distribution of each building's perimeter in two groups, active or passive façade, which are subdivided into different functional categories (e.g. transparent / direct access). This figure reveals that the majority of malls aim to supply active façades, but creating open, or transparent interfaces with the building's interior. Nevertheless, it is shown that some of the case-studies allocate 30% or more of their façade perimeter to passive functions (opaque walls and/or utilities).

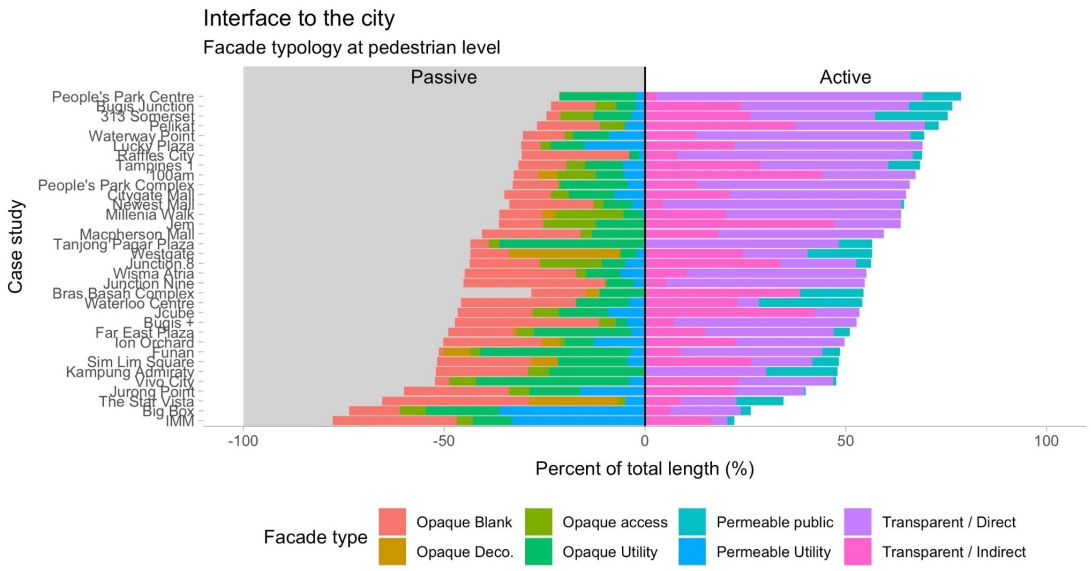

Figure 9: Diagram showing the proportion of the building facade allocated to 'active' or to 'passive' use.

Figure 10 shows analysis of the boundary perimeter, i.e. the proportion of the building perimeter (allocated to active use or other functions). Visually it reveals that the majority of case-studies preserve wide and/or open public spaces, but with undetermined use. The proportion of the building boundary that is allocated to activities (e.g. outdoor seating) is overall occasional, and low in comparison to other types of public space.

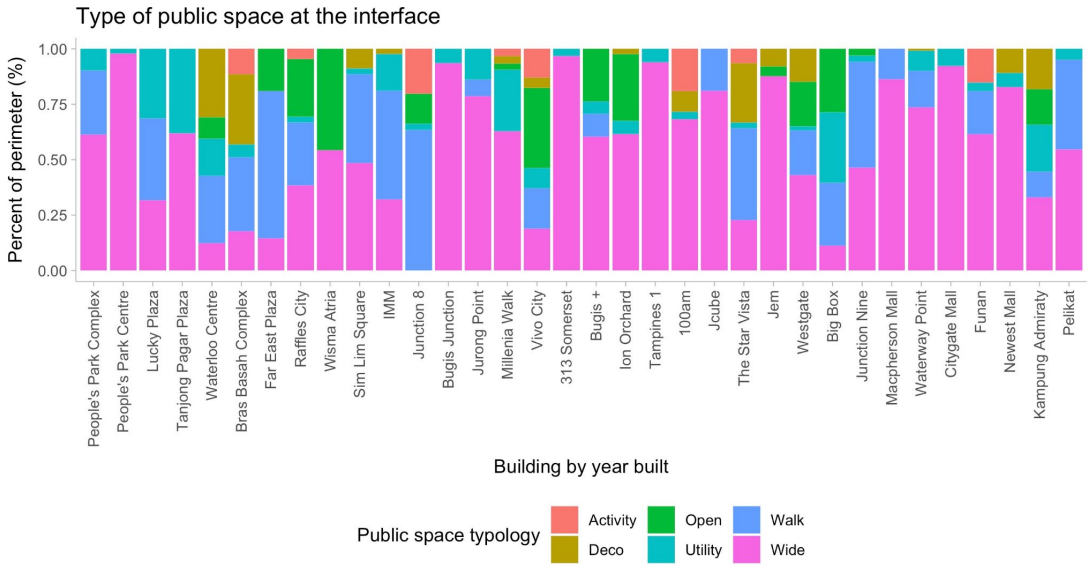

Figure 10: Stacked barplot showing the proportion of different typologies of public space along the perimeter of case-studies. Buildings (x-axis) are ordered by year built.

Civic interface

Turning to the overall way the interior circulation space and exterior façade of these case-studies create an interface with the urban realm, we compare the proportion of active façade against the average degrees of outdoor visual access (Figure 11). The proportion of active façade (y-axis) is

computed as the sum of façade lengths in *permeable*, *transparent & direct access* and *transparent / indirect access* categories, relative to the overall façade of the building (note that we did not include portions of the façade that are not possible to access (e.g. abutting walls with adjacent buildings). The average outdoor visual access represents the degrees of outdoor visual access averaged across all points of the interior circular grid; hence it captures the typical outdoor visual access of the interior and is less influenced by entrance grid points. To our knowledge, there are no objective guidelines about what constitutes 'good' outdoor visual access for commercial spaces, or the proportion of building façade that should be allocated to 'active' types. Nevertheless, by taking a median in each dimension, it can be observed that the case-studies vary greatly among them. Some achieve both an active façade and high (compared to others) average visibility towards the exterior space, thus providing an interface with the city. In contrast, others tend to interface with the city at a single level, e.g. only with an active façade, leaving an interior space isolated from the outdoor urban space. And others, finally, have limited engagement with the surrounding urban environment, providing limited active façade and limited outdoor visual access too. Notably, some of the malls with the larger footprint (shown here with the radius) score low in both dimensions.

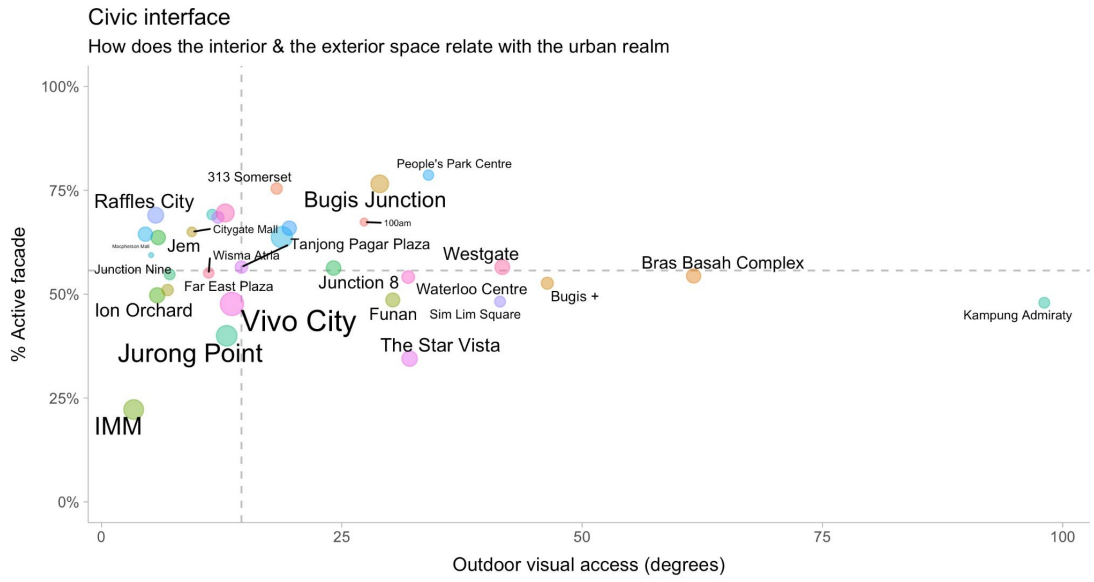

Figure 11: Scatter plot showing the proportion of Active facade (%, relative to total facade perimeter) against average outdoor visual access. Each case-study is represented as a dot (radius scales with surface area). Dashed lines indicate the median value of each axis. We can observe a wide range of how buildings generate urban space (active facades, y-axis) or relate to it (outdoor visual access, x-axis).

5 DISCUSSION

In this paper we explored the properties of the spatial configuration of multiple examples of the commercial mixed-use building typology, as it has developed in the tropical city-state of Singapore in the last 50 years. The motivation of this research lies in the observation that in many contemporary metropolises at tropical and sub-tropical climates tend to favour the development of shopping malls. Here we examine the different spatial variations of this typology of privately owned – yet public – buildings. Space syntax and spatial cognition research has demonstrated the relationship between built form, the spatial configuration of building layouts or urban fabrics, and behaviour patterns of people.

A large set of 34 case-studies of commercial buildings (shopping malls) were submitted to an urban design audit, spatial and space syntax analysis in order to enable a critical observation and the formulation of a taxonomy. The selected buildings provide a variety of examples of the podium-and-tower typology, and how it is implemented in transit-oriented developments.
The comparative analysis of multiple buildings (see also Araguez and Psarra, 2017) allows to develop a better understanding of typology and the trade-offs that are made during different stages of planning.

Our results show a few key observations. First of all, the mixed-use building typology appears stable in terms of size and urban space boundaries. Throughout several decades the plot median plot size, as well as the maximum, do not vary. This finding could be explained by the fact the majority of such developments takes place within the urban fabric (and not in suburban areas) and possibly also reflects the local planning regulations. Second, in terms of the building-city interface, which is related to active facades (more introvert or more extrovert), there does not seem to a clear trend and further research is needed to determine how this reflects developers priorities.

There are however major differences within the overall typology. While some buildings that are well embedded in their surrounding urban space, both contributing in the pedestrian realm with active façades and by integrating their interior space with the exterior through visual access, others tend to either provide only an exterior interface, or be introverted and cut-off from their surroundings. Using the isovist measure of outdoor visual access, we estimated how much of the surrounding urban realm can be perceived from the indoor spaces. This does not necessarily reflect the surrounding urban fabric and can also occur in buildings in central and walkable neighbourhoods.

In this case our results show that some of the buildings with the larger footprint (size, walkable area) are often those with the least scores in visual integration to their surroundings. These differences reflect design decisions, and could be attributed to various considerations, for example whether the building covers an entire city block, what the urban surroundings look like (presence of active land-uses, vs busy roads and highways). Nevertheless, the design decisions behind these spatial attributes of façade typology and outdoor visual access, have a long-term influence on the surrounding urban space, contributing to its walkability, liveability, vitality and imageability. In this context, it will be fruitful to complement the analyses presented here with the syntactical analysis of the layouts, by harnessing novel methods such as the *upper-bound projection intelligibility* (see Dalton et al., 2022), to understand how other aspects of the layout, such as intelligibility and complexity have evolved over the decades.

Taken together, these investigations of interface between the building and the city, focused specifically on the mixed-use podia of Singapore, provide a framework to understand the potential trade-offs that are made in the making of each building, and also suggest how each building relates

with the city around it. A formal comparative analysis (Figure 11) can be used to guide future planning decisions.

5.1 Limitations

This work has several limitations. First of all, It should be noted that this type of analysis only captures the latent properties of the architectural design. In many cases glass façades or entrances have been made opaque or closed, or objects block the visual access through a corridor. These changes may change how space is experienced, but are also temporary; so we focused on capturing the design intent Second, despite its breadth we could only analyse a subset of case-studies from the overall examples of the typology in Singapore. Third, we only analysed one of the floorplans for each building, typically the ground floor level where it interfaces with pedestrians. Because minor differences between the multiple floors of public and commercial buildings are common – indeed this is often a source of wayfinding complexity and confusion (Kuliga et al 2019) it is possible that other floors than those analysed have different properties. Informally we have observed that in most cases, the other floors (i.e. apart from the ground-floor) of building podia are in fact less transparent to the urban realm (outdoors). Fourth, we could only obtained publicly accessible floorplans which may have undocumented variations from the current floorplans. Last, in this work we have only included measures of spatial analysis to describe these buildings, without taking into account the lived experience of their occupants.

5.2 Future research directions

Future work includes to expand the case-studies, and address some of the limitations highlighted above. Likewise, the space syntax and spatial analysis used to describe them will be expanded using spatial metrics that capture users' perceptions and appraisals of their experiences in and of those buildings.

6 CONCLUSIONS

In this paper we examined the evolution of mixed-use buildings, specifically shopping malls belonging to the podium-and-tower typology. Our analysis focused in Singapore, where due to climate, real-estate, and planning policies, this typology has become popular for transit-oriented neighbourhoods and other urban developments. The analysis of floor plans from 34 shopping-mall located in the podium of mixed-use buildings, focused on the interface between the interior and the exterior space. Traditional types of urban design analysis that focus on this interface, such as active facades, were combined with isovist-based analysis of the relationship between indoor and outdoor space. Our results show the prevalence and large-scale footprint of the typology in Singapore. We further show that buildings differ with respect to how they interface with the city. Future work will expand the analysis of the building layout using space syntax methods and combine these with qualitative data from buildings users. These results provide an argument for studying this typology further and highlight how quantitative measures of the building-city interface can help understand and design better urban design guidelines for future developments.

ACKNOWLEDGEMENTS

The authors are grateful to Sarah Lee, Chee Seng Sih, and Céleste Richard for their assistance in this research. The research was conducted at the Future Cities Laboratory at the Singapore-ETH Centre, which was established collaboratively between ETH Zurich and Singapore's National Research Foundation (FI 370074016) under its Campus for Research Excellence and Technological Enterprise programme.

REFERENCES

Aragüez, M., & Psarra, S. (2017). Spatial and social patterns of an urban interior – The Architecture of SANAA. *Journal of Space Syntax*, *7*(2), 193–218.

Berghauser Pont, M. (2014). Innovations in Measuring Density: From Area and Location Density To Accessible and Perceived Density. *Nordic Journal of Architectural Research*, (2), 11–30.

Cervero, R., & Kockelman, K. (1997). Travel demand and the 3Ds: Density, diversity, and design. *Transportation Research Part D: Transport and Environment*, *2*(3), 199–219. https://doi.org/10.1016/S1361-9209(97)00009-6

Chang, S. (2000). A high-rise vernacular in Singapore's housing development board housing. *Berkeley Planning Journal*, *14*, 97–116. https://doi.org/10.5070/bp314112985

Dalton, N.S.C., Dalton, R.C., McElhinney, S. and Mavros, P. (2022) *Upper bound projection and Stochastic isovists*. In Proceedings of the 13th International Symposium on Space Syntax, Bergen, Norway.

Dovey, K., & Symons, F. (2014). Density without intensity and what to do about it: reassembling public/private interfaces in Melbourne's Southbank hinterland. *Australian Planner*, *51*(1), 34–46. https://doi.org/10.1080/07293682.2013.776975

Gehl, J., Kaefer, L. J., & Reigstad, S. (2006). Close encounters with buildings. Urban Design International, 11, 29–47. https://doi.org/doi:10.1057/palgrave.udi.9000162

Harwdick, J (2010) Mall Maker: Victor Gruen, Architect of an American Dream. University of Pennsylvania Press.

Hillier, B. (2012) 'Studying Cities to Learn about Minds: Some Possible Implications of Space Syntax for Spatial Cognition', Environment and Planning B: Planning and Design, 39(1), pp. 12–32. doi: 10.1068/b34047t.

Ibraeva, A., Correia, G. H. de A., Silva, C., & Antunes, A. P. (2020). Transit-oriented development: A review of research achievements and challenges. *Transportation Research Part A: Policy and Practice*, *132*(November 2019), 110–130. https://doi.org/10.1016/j.tra.2019.10.018

Kiang, H. C., & Liang, L. B. (2009). New Asian public space: Layered Singapore. *Urban Design International*, *14*(4), 231–246. https://doi.org/10.1057/udi.2009.24

Knowles, R. D., Ferbrache, F., & Nikitas, A. (2020). Transport's historical, contemporary and future role in shaping urban development: Re-evaluating transit oriented development. *Cities*, *99*, https://doi.org/10.1016/j.cities.2020.102607

Krukar, J., & Conroy Dalton, R. (2014). TOWARDS A UNIFIED MODEL OF BUILDING USABILITY. 22nd International Association People-Environment Studies (IAPS) Conference., 44(1), 1–5. https://doi.org/10.1007/s13398-014-0173-7.2

Kuliga, S. F., Nelligan, B., Dalton, R. C., Marchette, S., Shelton, A. L., Carlson, L., & Hölscher, C. (2019). Exploring Individual Differences and Building Complexity in Wayfinding: The Case of the

Seattle Central Library. *Environment and Behavior*, *51*(5), 622 –665. https://doi.org/10.1177/0013916519836149

Lang, W., Hui, E. C. M., Chen, T., & Li, X. (2020). Understanding livable dense urban form for social activities in transit-oriented development through human-scale measurements. *Habitat International*, *104*(July 2019), 102238. https://doi.org/10.1016/j.habitatint.2020.102238

Lau, S. S. Y., & Zhang, Q. (2015). Genesis of a Vertical City in Hong Kong. International Journal of High-Rise Buildings, 4(2), 117–125.

Loo, B. P. Y., Chen, C., & Chan, E. T. H. (2010). Rail-based transit-oriented development: Lessons from New York City and Hong Kong. *Landscape and Urban Planning*, *97*(3), 202–212. https://doi.org/10.1016/j.landurbplan.2010.06.002

Lu, Y., Gou, Z., Xiao, Y., Sarkar, C., & Zacharias, J. (2018). Do transit-oriented developments (TODs) and established urban neighborhoods have similar walking levels in Hong Kong? *International Journal of Environmental Research and Public Health*, *15*(3). https://doi.org/10.3390/ijerph15030555

Mcallister, C., Hill, F., & Mcallister, C. (2019). Active Frontage Controls : Architecture , Affordances and Atmospheres in Forrest Hill , Melbourne Active Frontage Controls

Natapov, A., Kuliga, S., & Dalton, R. (2015). *Building circulation typology and Space Syntax predictive measures Building circulation typology and space syntax predictive measures*. (September).

Ozbil, A., & Peponis, J. (2012). The Effects of Urban Form on Walking to Transit. *Eigth International Space Syntax Symposium*, 1–15.

Pafka, E., & Dovey, K. (2017). Permeability and interface catchment: measuring and mapping walkable access. *Journal of Urbanism*, *10*(2), 150–162. https://doi.org/10.1080/17549175.2016.1220413

Schneider, S., Bielik, M., Triemer, M., Tschetwertak, J., Donath, D., & Hollberg, A. (2014). Rapid Data Collection using Automated Model Generation and Performance Evaluation - A workflow for morphological studies of apartment floor plans. 32nd ECAADe Conference - Volume 2, 2, 303–311.

Seng, E. (2013). The Podium , the Tower and the " People ." Proceedings of the Society of Architectural Historians, Australia and New Zealand: 30, Open, 1, 219–232.

Shelton, Barrie. "1. Predisposed towards Mall Cities". Mall City: Hong Kong's Dreamworlds of Consumption, edited by Stefan Al, Honolulu: University of Hawaii Press, 2020, pp. 23-34. https://doi.org/10.1515/9780824855444-004

Steadman, P. (2014). The changing department store building, 1850 to 1940. Journal of Space Syntax, 5(2), 151–167.

Stojanovski, T. (2020). Urban design and public transportation–public spaces, visual proximity and Transit-Oriented Development (TOD). *Journal of Urban Design*, *25*(1), 134–154. https://doi.org/10.1080/13574809.2019.1592665

van Nes, A., & Yamu, C. (2021). Introduction to Space Syntax in Urban Studies. *Introduction to Space Syntax in Urban Studies*, 113–131. https://doi.org/10.1007/978-3-030-59140-3

Wee, K. N. L., & Tong, K. W. (2005). *The 4rs of asian shopping centre management*. Marshall Cavendish International.

Weisman, J. (1981). Evaluating Architectural Legibility: Wayfinding in the built environment. *Environment and Behavior*, *13*(2), 189–204. https://doi.org/10.1177/07399863870092005

Yang, P. P.-J., & Lew, S. H. (2009). An Asian Model of TOD: The Planning Integration in Singapore. In *Transit oriented development: making it happen* (pp. 91–106). https://doi.org/10.1068/a38377